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Noninvasive Determinations of Arterial Oxygenation and CO_2 Tension

MOST ARTERIAL BLOOD analysis is done to evaluate oxygenation (partial pressure of arterial oxygen [Pao_2]) and adequacy of ventilation (arterial carbon dioxide tension [$Paco_2$]). It is now technically possible to do these measurements noninvasively. Noninvasive determination of arterial O_2 saturation by transmitting two infrared wavelengths through the ear capillaries was developed in 1935 but was clinically unacceptable because of difficulties in calibration and inaccuracy in the clinical setting. Improved technology in the 1970s, using two to eight wavelengths, coupled with analysis of the pulse of arterial blood in the ear heated to 39°C, allowed for simplified calibration and clinically useful ear oximetry. Simultaneously, neonatologists found that the blood O_2 electrode applied to the skin heated to 44°C could give accurate estimates of Pao_2 when blood flow to the skin was adequate. Such measurements have largely replaced arterial blood gas analysis in neonatal intensive care units. In adults, the thickened skin (physiologic if not sociologic) made transcutaneous O_2 tension ($Ptco_2$) less reliable.

Similarly, the transcutaneous CO_2 pressure can be measured using either infrared transmission or the blood CO_2 electrode. Accuracy still depends on adequate blood flow to skin but less so than $Ptco_2$ since a continuous flux of CO_2 through the skin is not needed. CO_2 can also be measured in the exhaled air by infrared analyzers or mass spectrometry. The end-tidal CO_2 pressure ($Petco_2$) approximates $Paco_2$, and rebreathing methods can give better approximation of the mixed venous CO_2 pressure ($Pvco_2$).

These noninvasive methods are being increasingly applied clinically in the 1980s. As technology improves and becomes more familiar, their use can be expected to increase and replace arterial blood gas determinations in adult patients, as it already has in neonates. Several well-established applications for ear oximetry are as follows: to monitor for sleep apnea and hypoxemia during sleep studies; to adjust the amount of inspired O_2 at the bedside to achieve the desired O_2 saturation (usually more than 90% or a Pao_2 of more than 60 torr); to monitor oxygenation during exercise studies, and to monitor oxygenation in critically ill patients in intensive care units. These measurements should be verified by an initial simultaneous arterial blood analysis, particularly in a critical care setting or when the data are not consistent with the clinical assessment. Repeated arterial punctures to monitor oxygenation, however, are clearly no longer necessary or desirable.

Transcutaneous O_2 monitoring may also be used in the above settings but is more time-consuming to set up, requires higher temperatures (44°C), leaving a burn on the skin and therefore needs to be moved every three to four hours, and is more critically dependent on skin blood flow for accuracy.

Noninvasive monitoring of CO_2 is less common and usually applied to critically ill patients where ventilatory failure is imminent or present and endotracheal intubation and mechanical ventilation are indicated. A single skin electrode is now available to monitor both $Ptco_2$ and $Ptcco_2$. A single infrared unit can be used to alternately monitor both airway CO_2 ($Petco_2$) and $Ptcco_2$. The $Petco_2$ underestimates the $Paco_2$, and $Ptcco_2$ tends to overestimate the $Paco_2$. Monitoring both $Petco_2$ and $Ptcco_2$ can provide a bracket to estimate $Paco_2$. Changes in $Petco_2$ or $Ptcco_2$ indicate either changes in $Paco_2$ or in the gradient between $Paco_2$ and $Petco_2$. The $Paco_2$-$Petco_2$ gradient increases with abnormalities in ventilation (low tidal volume or maldistribution of ventilation), while the $Paco_2$-$Ptcco_2$ gradients increase when skin blood flow decreases or increases $Pvco_2$ due to metabolic changes. Therefore, a change in a noninvasive CO_2 measurement indicates either true $Paco_2$ changes, not uncommon in mechanically ventilated patients, or possibly a clinically significant pathologic change in ventilation, blood flow or metabolism. "Smart" alarm systems capable of analyzing such complex physiologic data to differentiate artifact from actual changes are technically possible, but the utility or necessity in a patient with critical ventilatory and circulatory problems is yet to be determined. For now, successful use of noninvasive CO_2 measurement depends on a "smart" and experienced critical care team.

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Home Oxygen Therapy

HOME OXYGEN THERAPY is indicated to correct hypoxemia and prevent the adverse cellular effects of hypoxia reflected in abnormalities of brain, heart and lung function. Hypoxemia is assessed by clinically evaluating a patient and by directly measuring arterial blood oxygen tension and saturation.

The management of hypoxemia due to chronic lung disease is the principal clinical indication for home oxygen therapy. Ongoing oxygen therapy should be prescribed for those patients who, after a month of optimal medical management, show a resting, nonrecumbent arterial oxygen tension of less than 55 mm of mercury or an arterial oxygen saturation of less than 85%. Patients with evidence of pulmonary hypertension, impaired mentation or erythocytosis qualify for home oxygen therapy if their arterial oxygen tension is less than 60 mm of mercury.

The National Institutes of Health Nocturnal Oxygen Therapy Trial showed the superiority of continuous over nocturnal oxygen therapy in the treatment of hypoxemia due to chronic obstructive pulmonary disease.

When hypoxemia occurs only during sleep, or when supine, and if the arterial oxygen tension falls to less than 55 mm of mercury or the oxygen saturation to less than 85%, oxygen therapy during sleep, or when supine, is indicated.